

The Importance of XRT Observations in Discriminating Between Impulsive and Footpoint Heating

Amy Winebarger¹, Roberto Lionello²,
Cooper Downs², Zoran Mikic²,
Jon Linker²

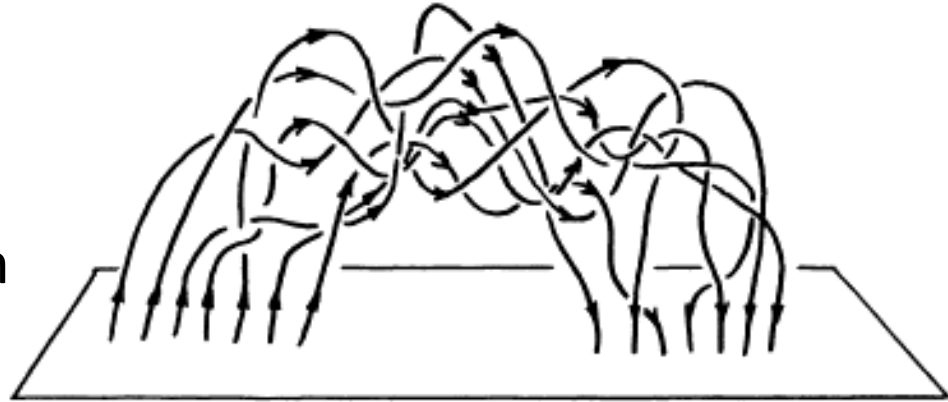
¹NASA MSFC, ST13, Huntsville, AL 35802

²Predictive Science Inc., 9990 Mesa Rim Rd., Ste. 170, San Diego, CA 92121-2910

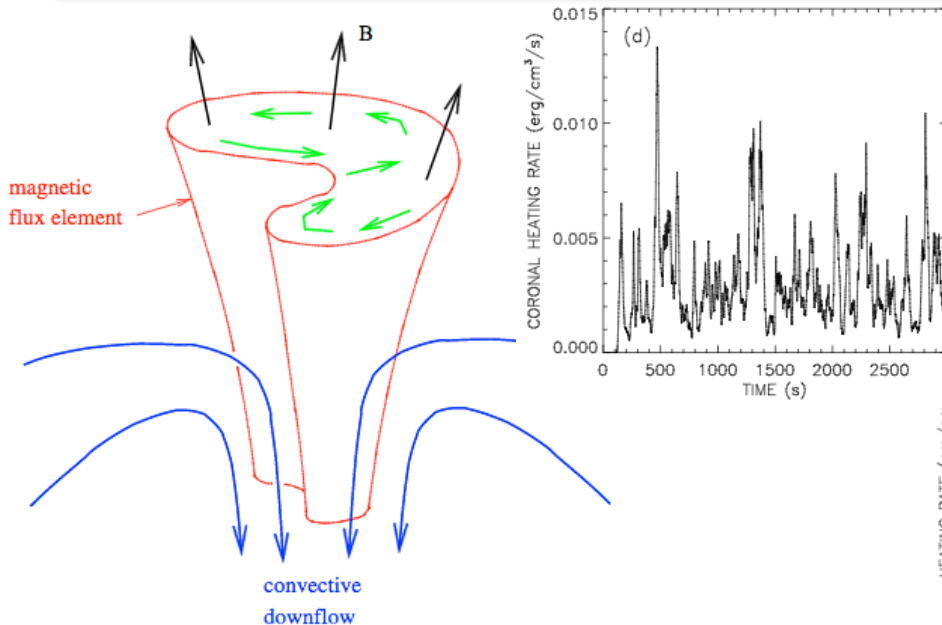
What heating mechanism?

“Impulsive”

- low frequency
- Nanoflares
- magnetic reconnection
- stressing models
- DC heating

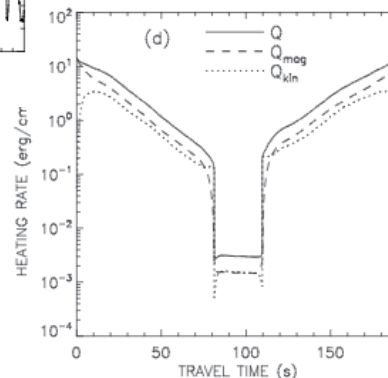


Parker, Sol. Ph., 1989, 121, 271



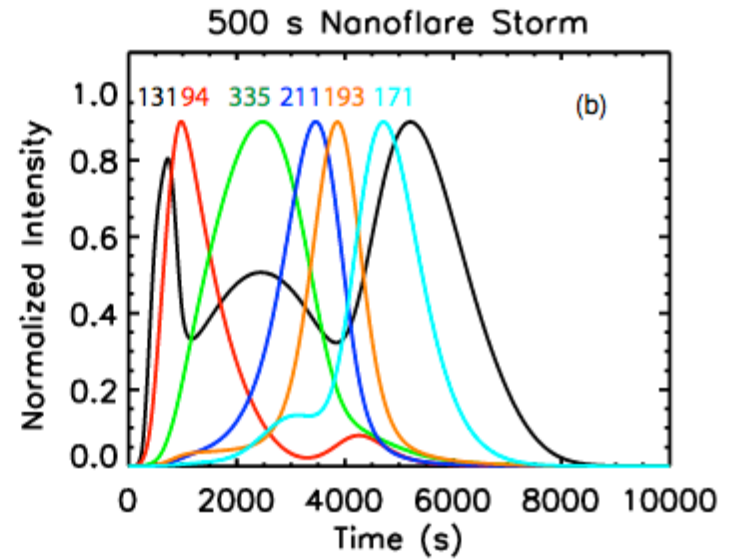
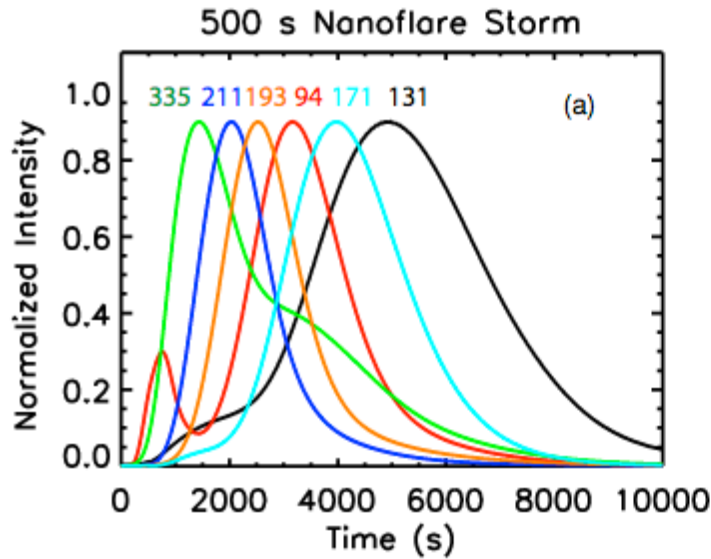
“Footpoint”

- Quasi-steady
- high-frequency
- Stratified
- wave dissipation
- AC heating

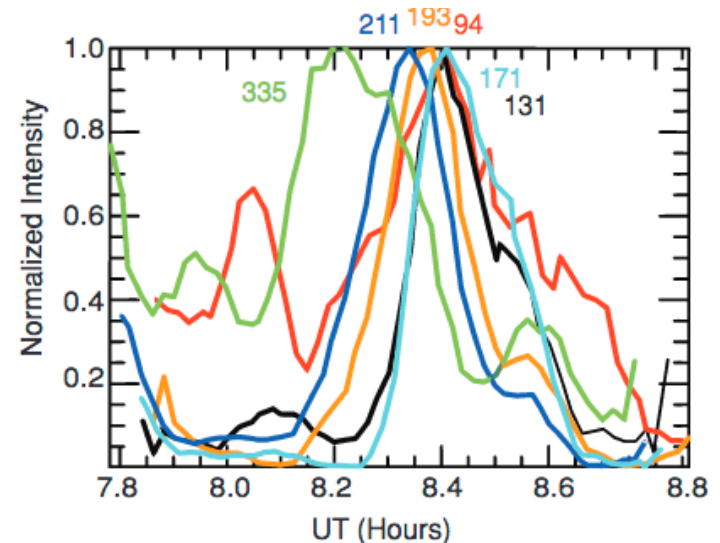
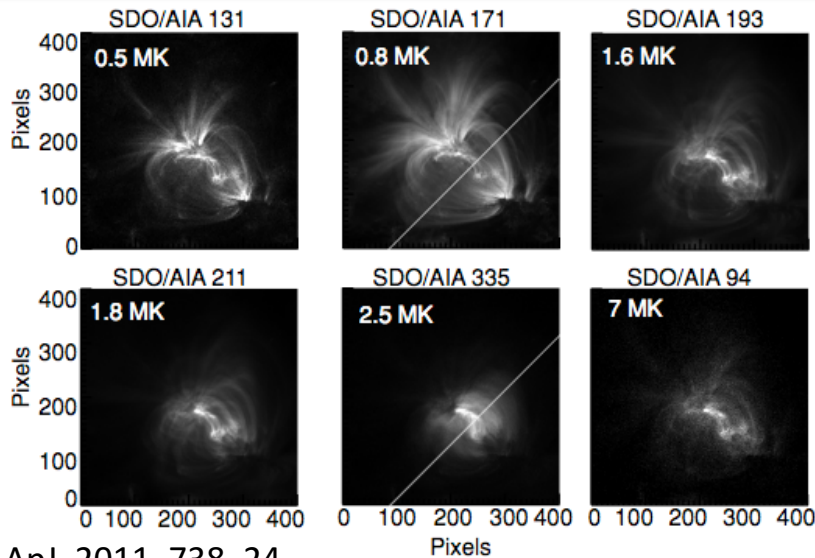


Impulsive heating = Cooling Loops

Hydrodynamic
Model Predictions
for Impulsive
Heating

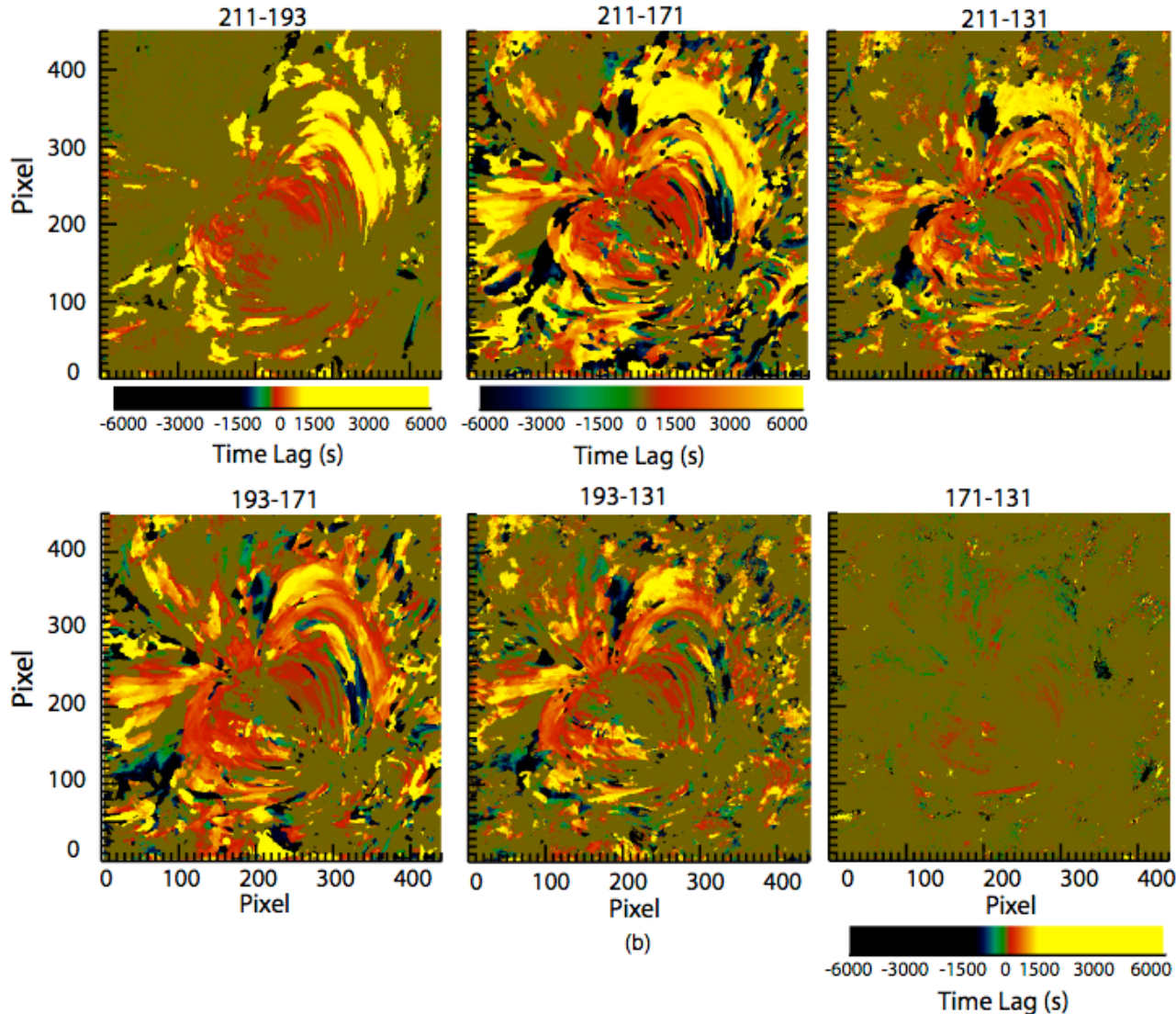


Observations



Cooling Loops Are Everywhere!

Time Lag Maps, 12-hr Windows



Red and yellow
imply the hotter
channel peaks
before the
cooler channel

Nanoflare Heating Proof?

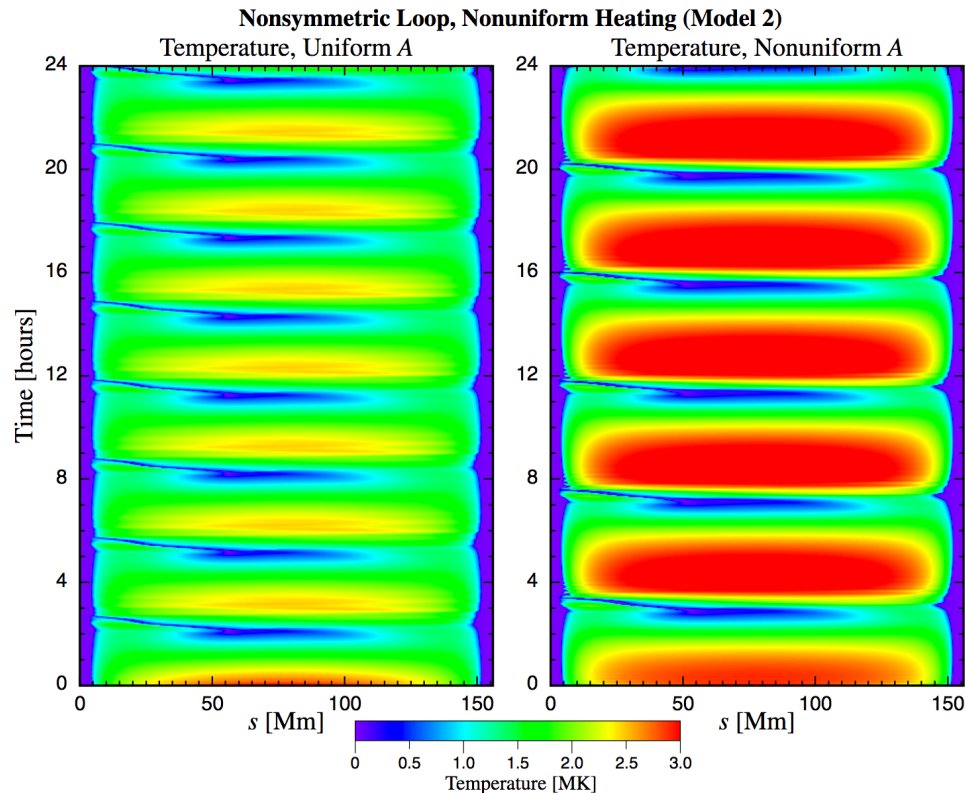
- Nanoflare heating predicts cooling loops
- Cooling loops are everywhere
- Nanoflare heating must heat the corona
- QED

1) Qualitative comparisons between the observations and models is lacking

- Don't know the true geometry of the coronal structures
- Don't know the abundance
- Don't know the density evolution

2) Footpoint heating can also generate cooling loops

Footpoint heating



Highly-stratified heating can cause thermal non-equilibrium (TNE).

Qualitatively, this looks identical to nanoflare heating

Mikic et al., ApJ, 2013, 773, 94

Additional observational evidence of TNE:

- Coronal rain (e.g., Antolin et al., ApJ, 2010, 716, 154)
- Long term oscillations in EUV loops (e.g., Froment et al. ApJ, 2017, 835, 272)

Statement of the problem

Both impulsive heating and footpoint heating predict cooling loops.

There is additional observational evidence for both impulsive and footpoint heating

How can we differentiate between impulsive and footpoint heating?

IDENTIFYING OBSERVABLES THAT CAN DIFFERENTIATE BETWEEN IMPULSIVE AND FOOTPOINT HEATING: TIME LAGS AND INTENSITY RATIOS

For additional information,
see paper.

Amy R. Winebarger,

NASA Marshall Space Flight Center, ZP 13, Huntsville, AL 35812

`amy.r.winebarger@nasa.gov`

and

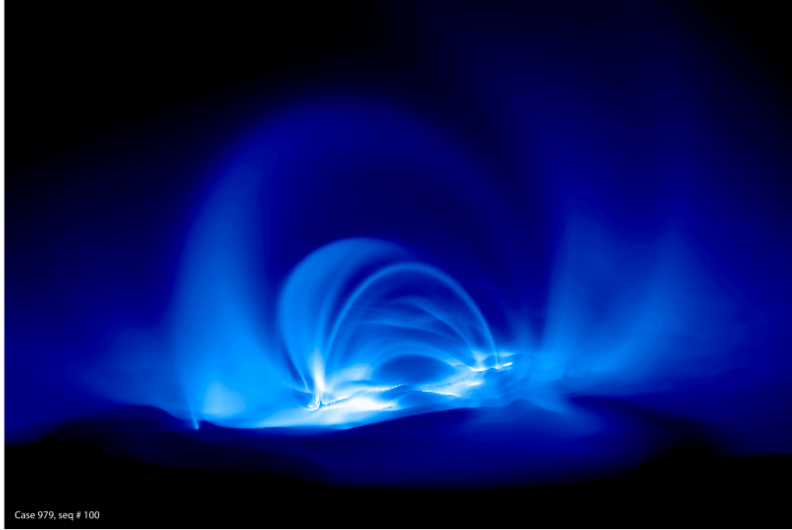
Roberto Lionello, Cooper Downs, Zoran Mikić, Jon Linker

Predictive Science, Inc., 9990 Mesa Rim Rd., Ste. 170, San Diego, CA 92121-2910

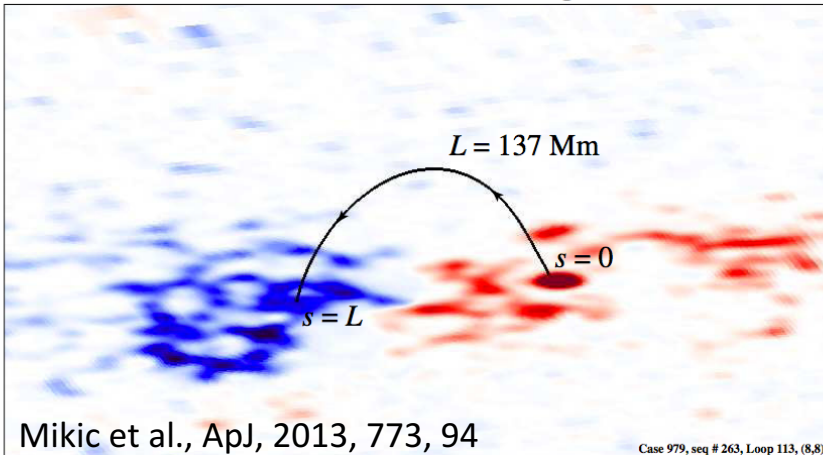
`{lionel, cdowns, mikicz, linkerj}@predsci.com`

Scope of this study

Simulated EIT 171 Å Emission from AR 7986 (August 1996)



Field Line from a 3D Active Region Simulation
NLFFF Model of AR 7986, August 1996



Mikic et al., ApJ, 2013, 773, 94

Case 979, seq # 263, Loop 113, (8,8)

Selected a *single field line geometry*

Varied :

- stratification of heating
- impulsive heating magnitude

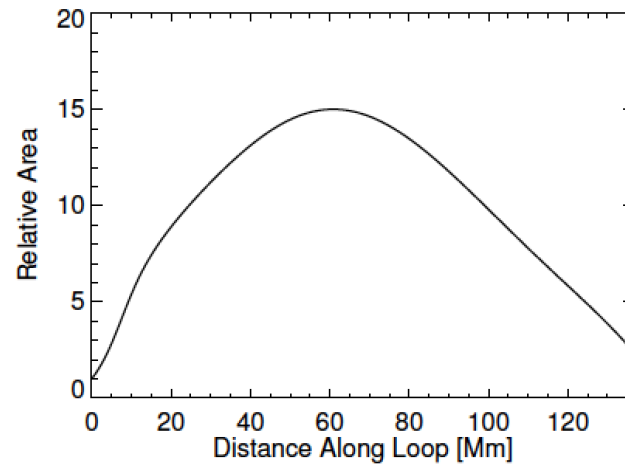
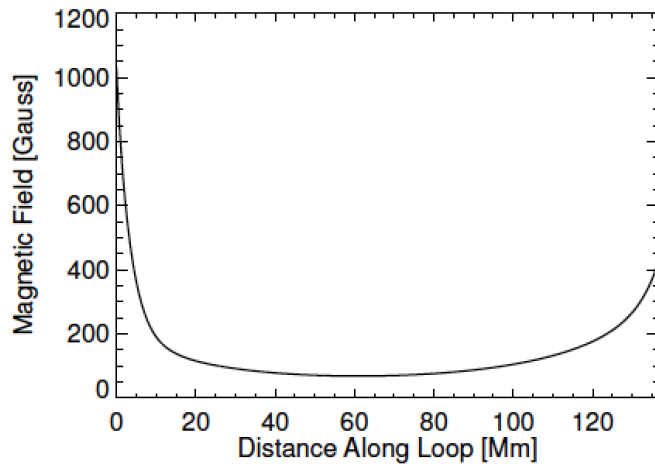
Calculated:

- AIA and XRT lightcurves
- timelags between channel pairs

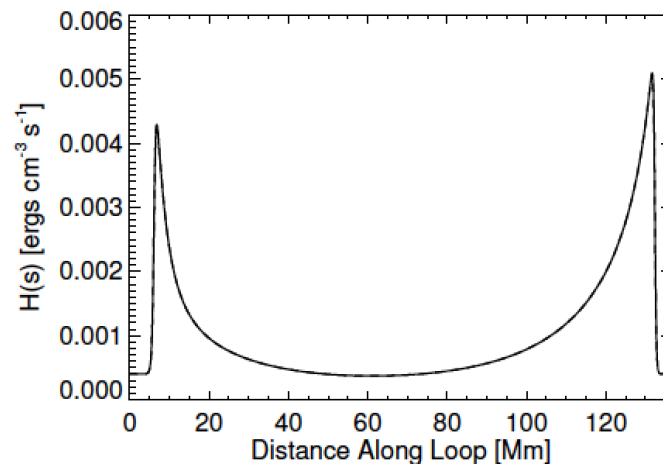
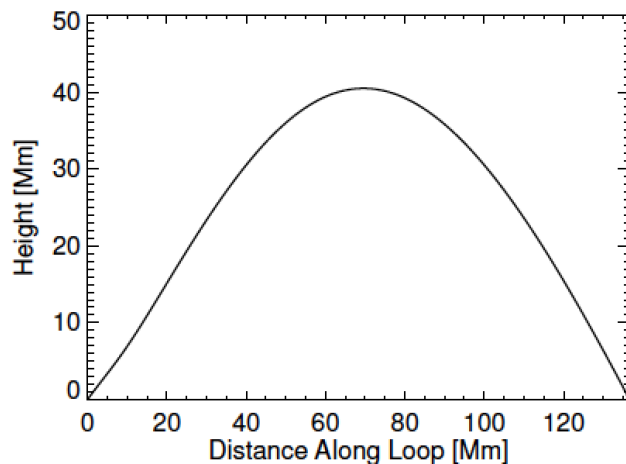
Conclusions:

XRT to AIA time lags can discriminate between heating mechanisms

Step 1 – Establish the Geometry and Initial Heating Profile

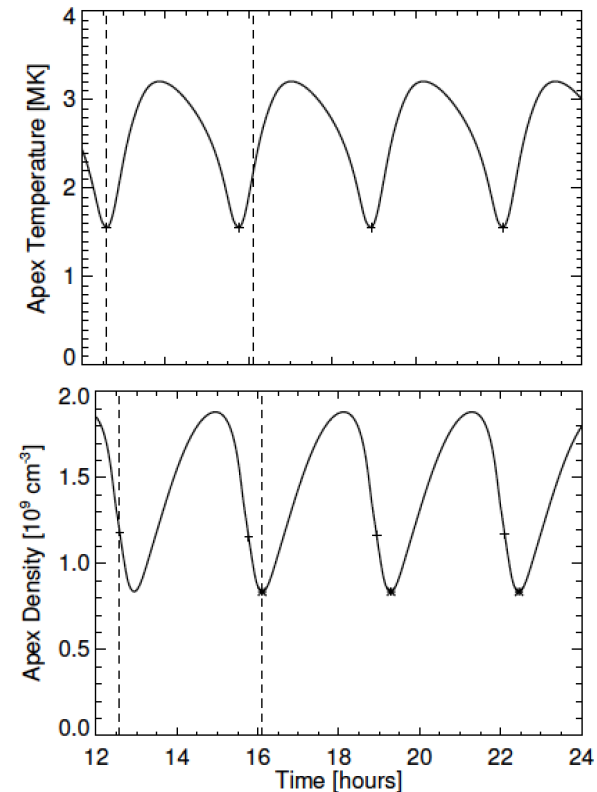
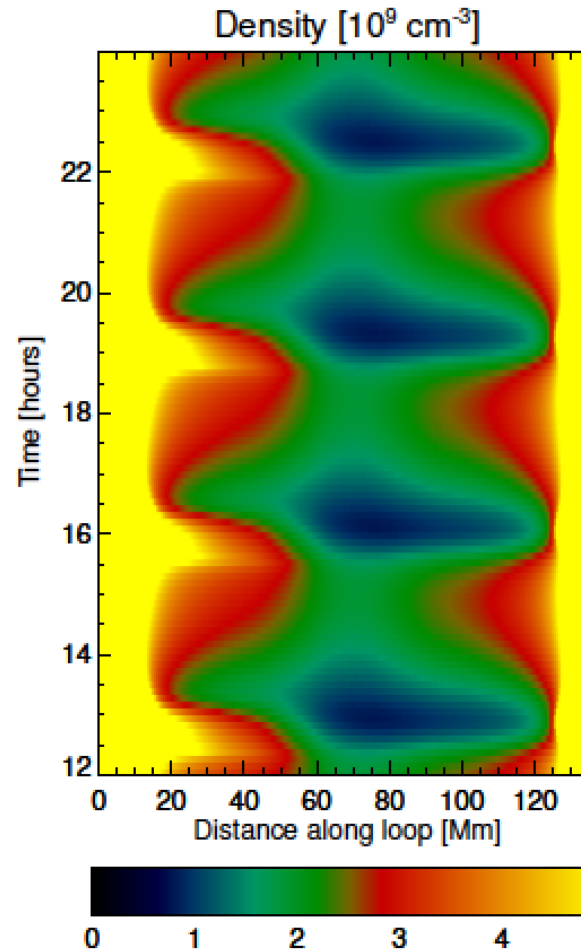
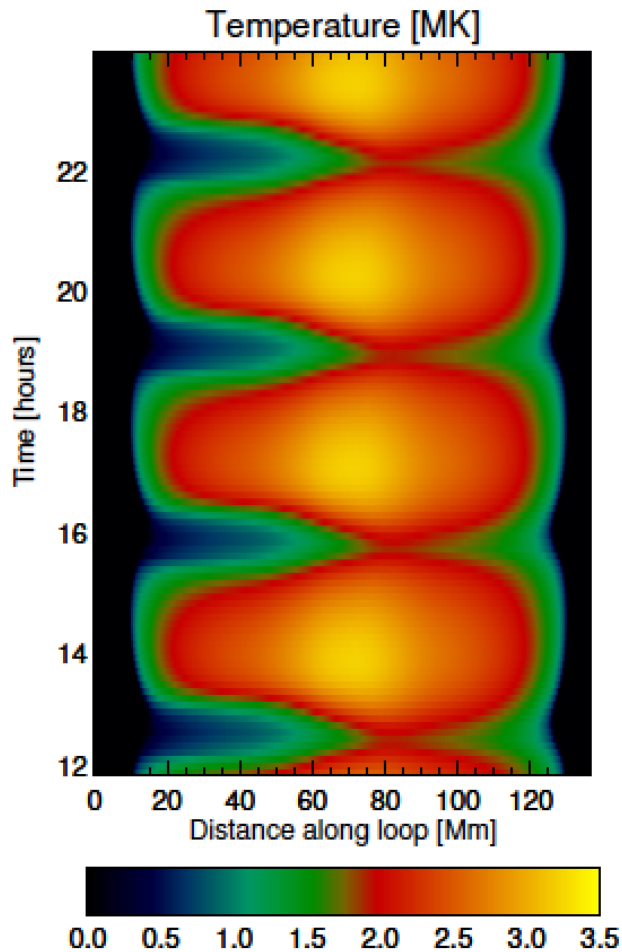


Used loop geometry and heating profile from Mikic et al., ApJ, 2013, 773, 94

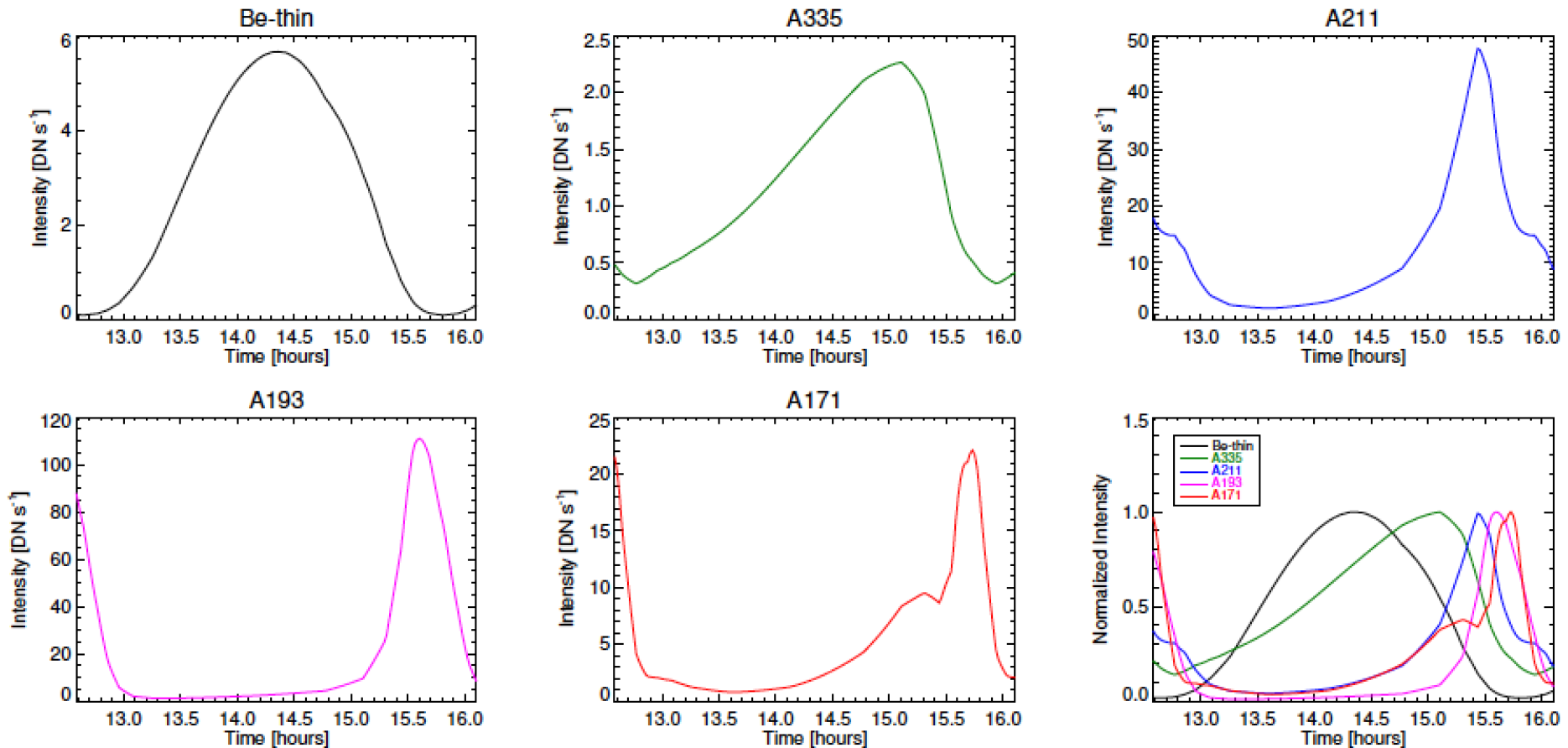


Step 2 – Solve 1D Hydrodynamic Simulations

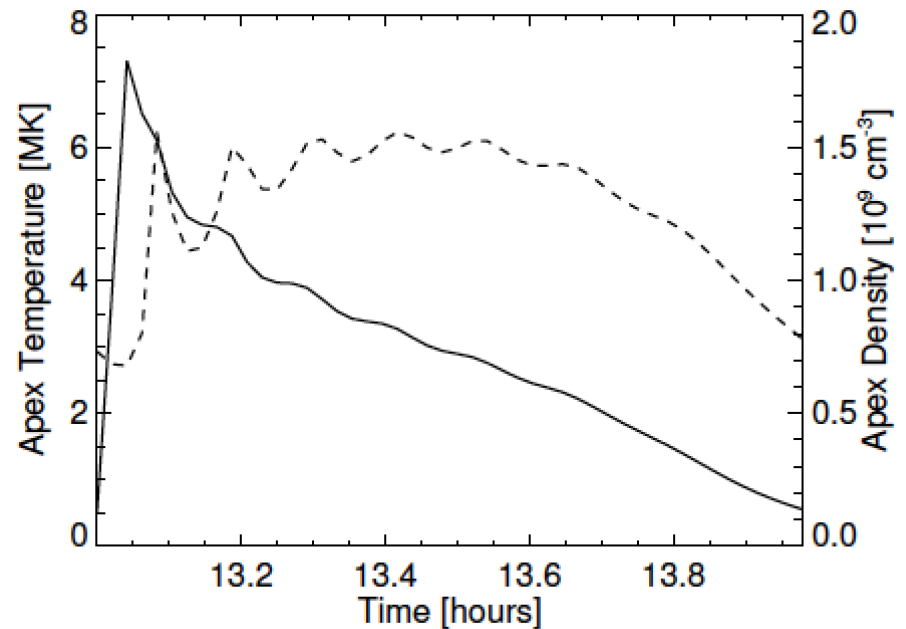
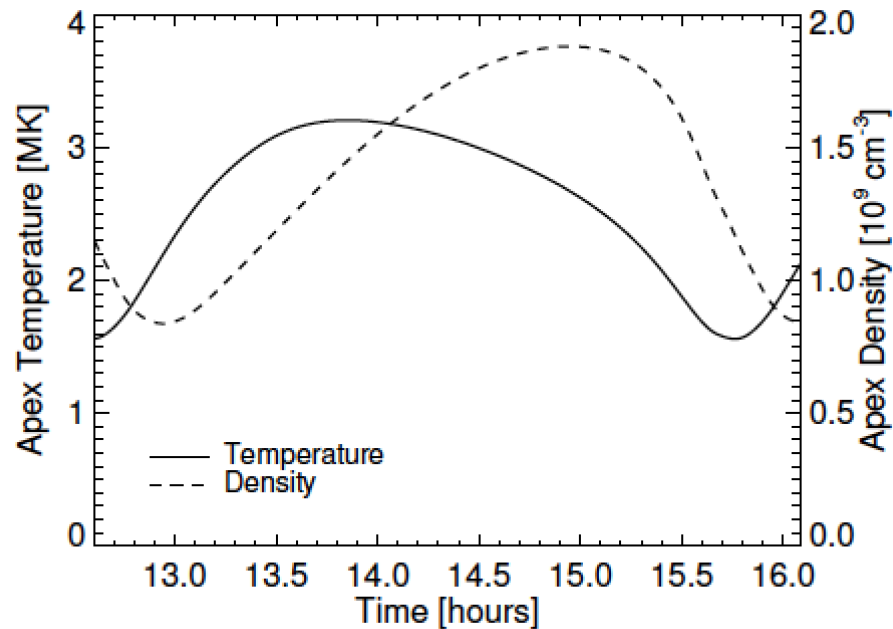
Used Predictive
Science One-
dimensional
Code



Step 3 – Calculate Lightcurves

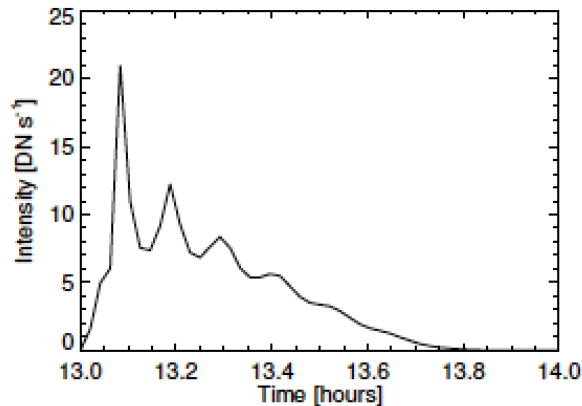


Step 4 – Repeat for Impulsive Heating with Same Average Heating Rate

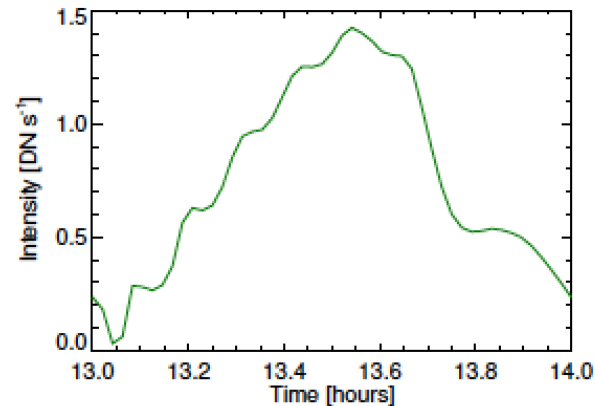


Step 4 – Repeat for Impulsive Heating with Same Average Heating Rate

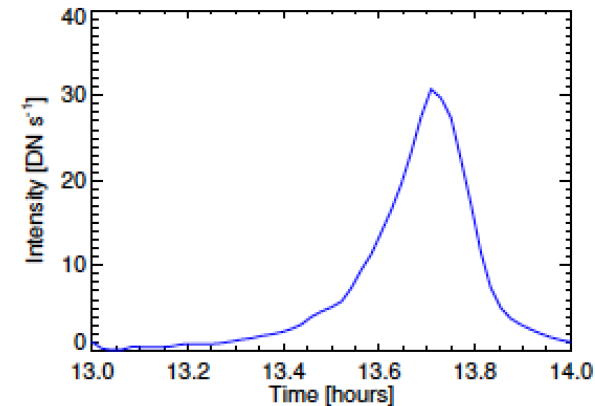
Be-thin



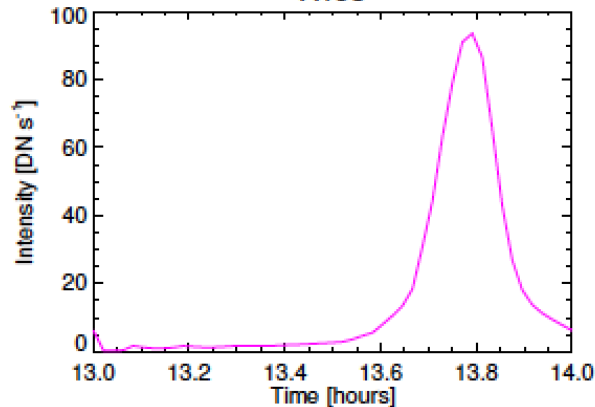
A335



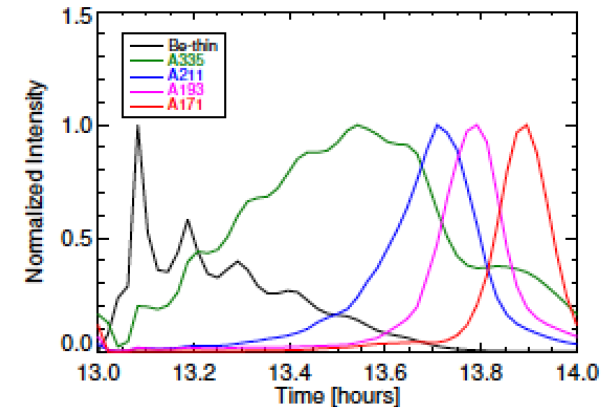
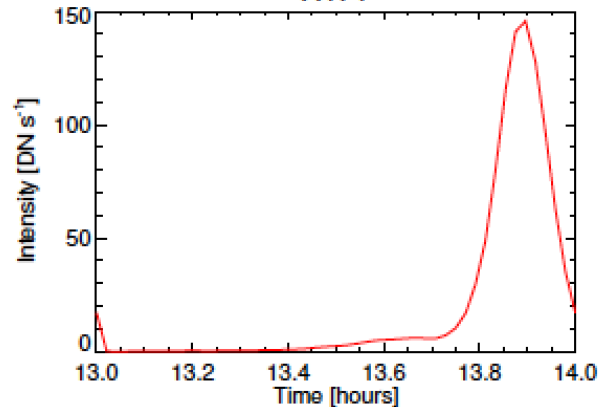
A211



A193



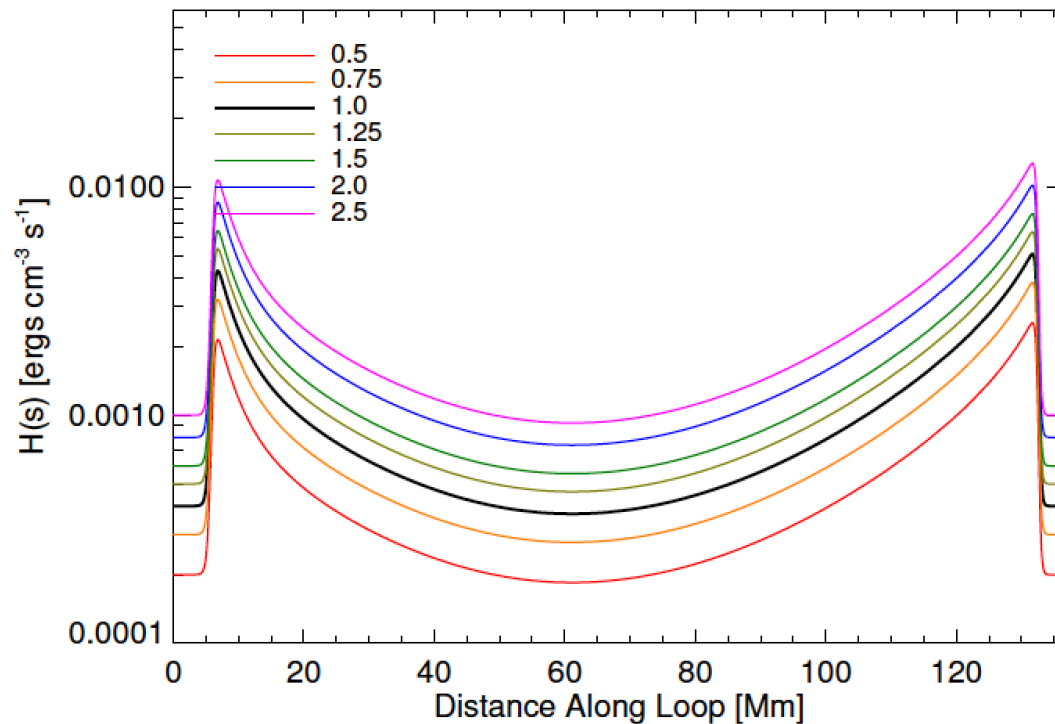
A171



Step 5 – Compare Timelags

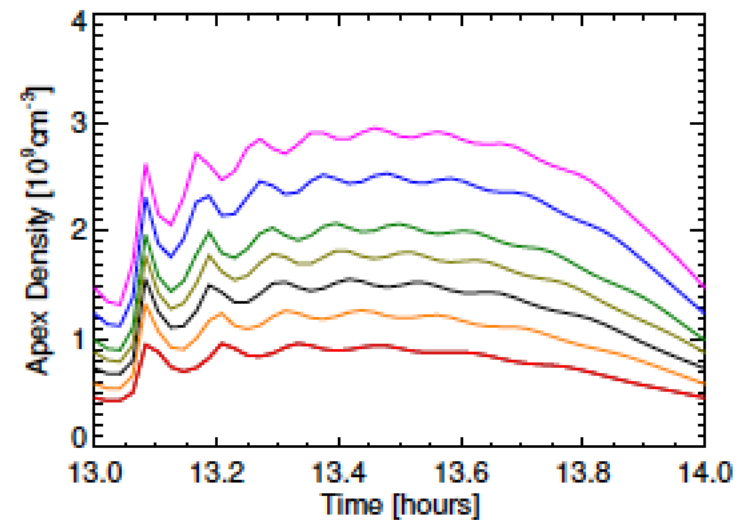
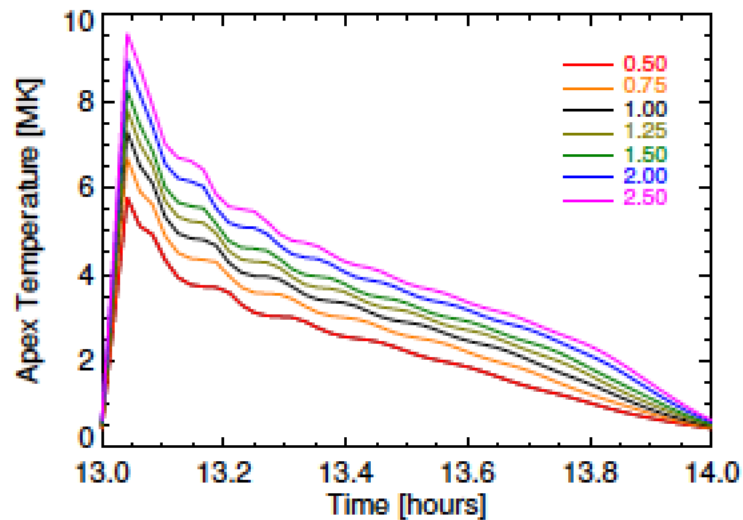
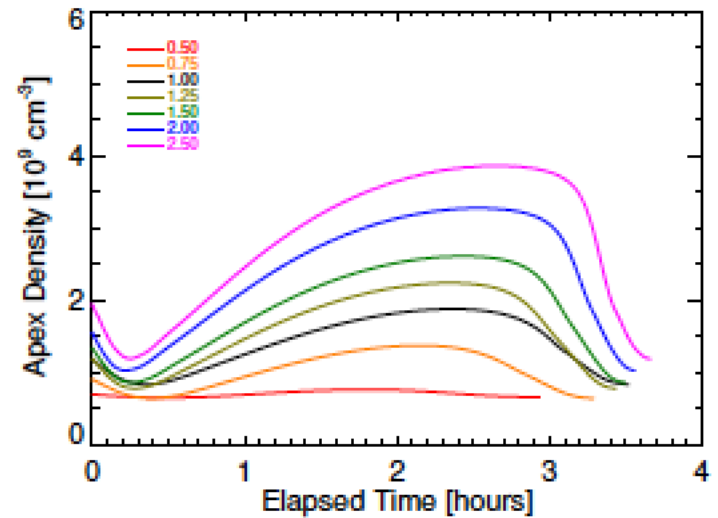
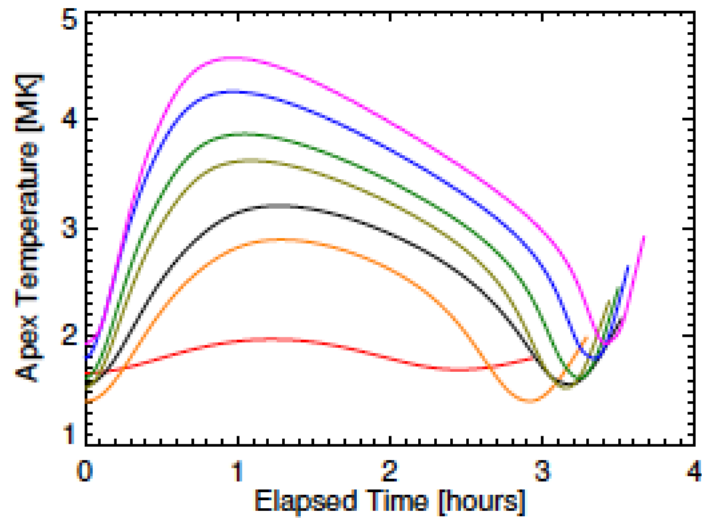
Channel Pair [Ch. 1 - Ch. 2]	Footpoint Time Lag [s]	Footpoint Int. Rat. [Ch. 2 / Ch. 1]	Impulsive Time Lag [s]	Impulsive Int. Rat. [Ch. 2 / Ch. 1]
Be-thin-A335	990	0.40	1200	0.07
Be-thin-A211	3870	8.43	1950	1.47
Be-thin-A193	4830	19.60	2340	4.46
Be-thin-A171	4230	3.90	2760	6.91
A335-A211	1770	21.06	510	21.58
A335-A193	2430	48.99	840	65.71
A335-A171	2070	9.76	1230	101.73
A211-A193	690	2.33	240	3.04
A211-A171	780	0.46	630	4.71
A193-A171	0	0.20	390	1.55

Additional Analysis

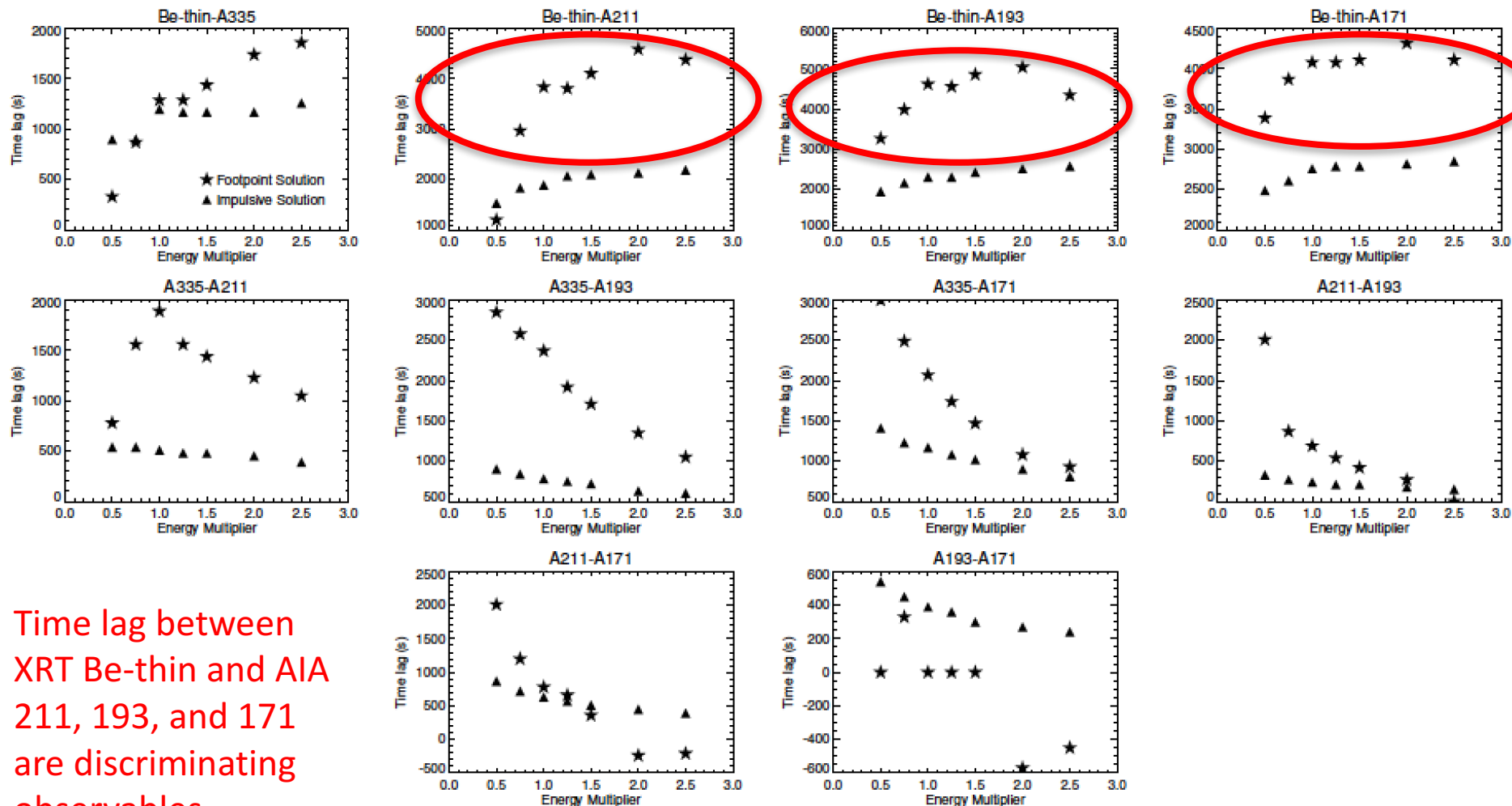


Completed identical analysis for multiples heating magnitudes for footpoint and impulsive heating.

Additional Analysis



Results



Time lag between
XRT Be-thin and AIA
211, 193, and 171
are discriminating
observables.

Conclusions

- Cooling loops can be explained by both impulsive and footpoint heating.
- AIA time lags alone may not be enough to discriminate between them.
- Adding a high temperature channel (like XRT Be-thin) improves diagnostics.